NBS-GCR-88-550

Design Concepts for Safer Matches and Lighters

Trident Engineering Associates, Inc.

September 1972

Issued August 1988

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U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Fire Research
Gaithersburg, MD 20899

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DESIGN CONCEPTS FOR SAFER MATCHES AND LIGHTERS

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Notice

This report was prepared for the Center for Fire Research of the National Engineering Laboratory, National Bureau of Standards Under Contract Number 2-35999. The statements and conclusions contained in this report are those of the authors and do not necessarily reflect the views of the National Bureau of Standards or the Center for Fire Research.

A REPORT MADE TO:

THE OFFICE OF FLAMMABLE FABRICS
NATIONAL BUREAU OF STANDARDS

BY

TRIDENT ENGINEERING ASSOCIATES, INC.
ANNAPOLIS, MARYLAND

NBS Contract No. 2-35999

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DESIGN CONCEPTS FOR SAFER MATCHES AND LIGHTERS

September 29, 1972

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DESIGN CONCEPTS FOR SAFER MATCHES AND LIGHTERS

ABSTRACT

A match or cigarette lighter is frequently the source of ignition in fires involving the accidental burning of fabric items. Consequently, any design of book matches or lighters which would contribute to their utilization in a safer manner would be highly desirable.

In this report, eight design modifications for book matches and seven modifications for cigarette lighters are described and discussed. The objective of the new designs is to prevent the accidental ignition of clothing or other fabric material when used by children in a play situation or when used for a bona fide application by the adult population. The designs proceeded from a study of ignition sequences gleaned from accident reports filed with the National Bureau of Standards.

A review of the reports revealed that, of the accidents in which matches and lighters were a factor, the majority were match-related and occurred in the 0-10 age group. Based on these findings, emphasis was placed on developing a safer match design for the protection of the very young. In order to apply some quantitative index of value, a rating system was devised in which added safety, anticipated acceptance by the public and costs were considered to ascertain the net value of each concept. The judgments of the investigators, when applied to the rating system, indicated the following:

> A matchbook designed with a sleeved striker which requires insertion of a thin match and coordinated action of both hands, is the most promising. The coordination required is the squeezing of the match head and the simultaneous pulling of the match stem.
>
> A lighter concept which utilizes a screened flame is considered the most desirable.

Other designs also show a reasonable degree of improvement and it is a conclusion of this report that one or more of the designs described herein, if adopted, will lead to increased safety for the entire population.

Key Words: Matches; lighters; ignition hazards; fire injuries; ignition sources; burns; fabric fires; flammable fabrics

INTRODUCTION AND STATEMENT OF THE PROBLEM

A proposal was submitted to the National Bureau of Standards on March 28, 1972, to study the involvement of matches and lighters as ignition sources in fabric item fires as reported in the Flammable Fabrics Accident Case and Testing System and to develop design changes that will result in a reduction in the ignition hazard they present. The study was divided into three phases:

Phase I:	Determine accident circumstances and ignition sequences, apply vigorous doses of imagination, and create concepts of match and lighter design to eliminate or reduce the hazard of unintended ignition. The major thrust in this phase would be to produce innovative ideas as a stimulus to further thinking. An estimate of the real impact of economic factors and acceptance by the public is to be broad and qualitative in nature. Such factors are to be considered in detail at a later date.
Phase II:	Construct working models of concepts developed in Phase I. Make refinements in design as necessary.
Phase III:	Subject promising models to tests of safety and to acceptance by the public and by manufacturers.

Further details of each phase are contained in Appendix II. This is a report of the work done in Phase I under Contract Number 2-35999.

CONCLUSIONS

1. A reduction of the hazard of clothing ignition accidents associated with matches and lighters can be achieved by modifying current designs.

2. Changes in design, as described by some of the concepts contained in this report, should be acceptable to the public.

3. The most promising design concepts are the sleeved striker plate matchbook together with its modifications, and the Davy Cage screened lighter.

4. The safety features incorporated in all of the designs would be most beneficial to young children, if adopted.

5. While safety was sought primarily for an age group up to 10 years of age, these designs would also provide added safety for the remainder of the population.

RECOMMENDATIONS

1. As stated in the introduction to this report, a major objective of Phase I is to provide ideas that would be a stimulus to further thinking on the problem of match and lighter ignitions of fabric items. Therefore, it is recommended that the findings of this study receive a wide distribution, that further ideas and comments be solicited and that these ideas and comments be summarized for inclusion in any effort undertaken in Phase II.

2. It is further recommended that Phase II be implemented at an early date with the following changes:

   A. Based on the Phase I report and additional ideas generated by that report a process of elimination should be undertaken by the contractor and NBS to select two or three of the most promising match concepts, and a like number of lighter concepts, for further testing and evaluation.

   B. A sufficient number of prototypes of the selected designs be made to carry out any testing and evaluation required by Phase III.

   C. Concurrent with (B), planning of tests to be conducted in Phase III be done in Phase II. Phase III would then simply be an execution of the modus operandi developed for it in Phase II and an evaluation of test results.

SUMMARY

- Accident sequence data for this study was obtained from:

  (a) National Bureau of Standards Report 10,629 - "Ignition Sources in Accident Cases Involving Flammable Fabrics" by Henry Tovey and Richard Giroux
  (b) "Matches and Lighters, Observations" FFACTS, November 23, 1971
  (c) A perusal of randomly selected individual reports on accidents obtained by NBS from the Department of Health, Education and Welfare.

- The above mentioned documents revealed a different accident situation depending upon age grouping of those involved:

  (a) Under about 10 years old accidents occurred in play situation
  (b) Above about 10 years old accidents occurred while there was a deliberate and conscious use of the match or lighter.

  The highest percentage of accidents occurred in group (a).

- Based on these findings the investigators directed their safety efforts at the 0-10 age group. It was felt that safety improvement for this group would also benefit the elderly and handicapped persons. However, in the latter case, the safety advance suggested would entail some inconvenience to the elderly.

- The above mentioned documents also showed matches to be involved about five times as frequently as lighters. Consequently, primary emphasis was placed on a safe match design.

- A number of suggested designs for safe matches and lighters were then developed and are presented herein.

- A rating system was devised for each concept with regard to added safety, anticipated acceptance by the public and cost to the manufacturers. From these three factors an overall index of desirability was obtained by multiplication. The rating system reflects the best judgment of the investigators.

Standards for comparison are the current American book match and a commercially available, inexpensive lighter. A sleeved striker matchbook plus a thinner match, as described herein, were given the highest overall index and represent the most desirable innovations according to the investigator's rating system. Opinions of professional educators and of safety experts were solicited for these concepts. Their judgment indicated a good safety advance was possible for children 5 and under with this design because it required the coordination of both hands.

The only other attribute children were considered to have that might be taken advantage of was their short attention span. No definitive time range is to be found. New thinking in this area is now underway by educators. However, a general consensus was that 5 or 6 attempts would discourage young children from continuing to play with matches or lighters. This is only an opinion and should not be taken to apply universally.

The ultimate judgment on the efficacy of any new concept must await further testing and evaluation.

THE DATA BASE

The data base for this study consisted of some 1700 accident reports filed with the National Bureau of Standards (NBS).

These reports have been gathered from public safety organizations, especially the Food and Drug Administration (FDA), and state and local fire department. FDA investigators from 39 district offices in the United States compile reports on accidental fires involving fabric products and, where possible, they also obtain samples of any remains of these products. The reports and samples are forwarded to NBS where the information is evaluated for incorporation into a data bank. A system known as the Flammable Fabric Accident Case and Testing System (FFACTS) has been devised at NBS to systematically process and analyze the reported data. As many as 200 data elements can be coded for each fire accident case. The encoded data are derived from the report on the accident case, and they include information on the time and location of the accident, personal and socio-economic facts about the victim, extent of injury and losses, the sequence of events leading to the accident, and the nature of involvement of the fabric product. Data derived from laboratory tests performed on the remains of the fabric products involved in the accident, such as data on fabric construction and fiber content, and the results of flammability tests, are also encoded (1, 2).

RESULT OF DATA BASE STUDY

A. IGNITION SEQUENCE - MATCH FIRES

Approximately 70 cases of match-related fires were chosen at random for review from some 288 cases available. A distinct pattern emerged for the ignition sequence in each of four age groups: very young - 10 years of age and under; young - about 11-17; the adult group - about 18-60; and elderly - over 60. Needless to say, these age categorizations are not precise. The ignition sequences were apparently as follows:

1. Age 10 and Under

In every one of the 70 cases studied the child was in a room unattended. The child struck the match while playing and one of three things happened:

(a) The child dropped the match and ignited his own clothing.
(b) Sparks from the match ignited the rest of the book and the child threw the book which, in most cases, ignited some other fabric such as another child's clothing or a bedspread.
(c) Sparks from the match ignited some fabric such as the child's clothing.

2. Age 11-17

Here, there was a conscious use of the match for some purpose. The individual by this time was apparently aware of the danger of matches and fire but had not yet gained respect for the consequences. An intermediate material* was more frequently present than not. In a few cases, play was involved, such as in lighting grass or a firecracker. In others, the victims were engaged in a work situation with a flammable liquid and lit the match with the objective of cleaning up something, not realizing that some of the flammable liquid had spilled on him

---

* Intermediate material is any other non-fabric flammable substance.

3. Ages 18-60

The match fires in this group often accompanied lighting a cigarette. Direct ignition of clothing was normally involved. The overwhelming desire for a cigarette seemed to cause the victim to move hastily and to disregard the dictates of common sense.

Four of the most common sequences of ignition were:

(a) Sparks from the match ignited the victim's clothing.
(b) The match broke and fell onto the victim's clothing.
(c) The match was dropped or placed on the victim's clothing.
(d) In a few cases the victim had just tried to fill a cigarette lighter and had spilled fluid. The lighter became soaked and did not ignite. Instead of cleaning up first, the victim grabbed for some matches and ignited the fluid which had spilled onto his clothing.

4. Age 60 and Over

In this category a lack of muscle coordination was the major problem. The victim dropped a match and was unable to respond quickly enough to remove it from his clothing.

B. IGNITION SEQUENCE - LIGHTER FIRES

In these cases there was insufficient evidence to show a sequence as markedly clear as in the case of match accidents. However, the following patterns emerged in a study of some 50 of about 60 cases in the data base.

1. Children 10 and Under

The two sequences observed most often were:

(a) The victim was playing with the lighter and dropped it onto himself.
(b) A child deliberately ignited the clothing of the victim knowing they would burn but not realizing the speed with which combustion would proceed.

2. Ages 11-17

The pattern was not as clear as for the cases involving matches but again it appears there was most often a deliberate attempt to ignite some intermediate, flammable material.

3. Ages 18-60

There were an insufficient number of cases in this category to establish a pattern. However, approximately 25% of those cases available were related to smoking.

4. Age 60 and Over

In most cases in this age group, the victim had been trying to fill his lighter with fluid and had spilled the fluid onto his clothing. Ignition of the lighter then resulted in clothing ignition.

C. NOTES ON IGNITION SEQUENCES

1. In the great majority of cases, the fabric ignited was a fuzzy or raised surface material. Such materials have a large surface area and are easily ignited.

2. Adults apparently are inclined to strike matches toward themselves with a greater force than is necessary producing a heavy shower of sparks or breakage of the match.

METHOD OF PROBLEM SOLUTION

With the results of the data base studies in hand, the investigators searched patent records for any inventions which might have been usable in making an advance toward safer matches and lighters. A search of match patents yielded negative results. Lighter inventions were numerous. A review of these revealed no striking feature, not already on the market, which would be useful for the purpose of this study. Consequently, all the concepts which follow, save one, are inventions produced from the imaginations of the investigators.

A qualitative judgment by the reader on any of the concepts should be made with the above in mind as well as with a review of Appendix I, which contains a synopsis of the philosophy of the investigators. It is sufficient to state here that the greatest effort was directed at matches and the 0-10 age group. An attempt was made to take advantage of one or more of the three behavioral patterns children have. These are:

1. Poorer coordination than adults.
2. Less capability than adults to learn a sequence of operations.
3. An attention span shorter than adults.

The most promising concepts would be those including an operation designed to take advantage of poorer coordination.

DESIGN CONCEPTS

MATCHES

Eight match concepts are recommended and discussed below. A sleeved striker concept and its modifications are listed first. This is because a combination of all the modifications led to the highest overall index for this design when the rating system was applied to all the concepts. Thereafter, the remaining concepts were listed in a decreasing order of effectiveness in reducing the hazards of unintended ignitions. The more effective designs would be those which would prevent or discourage children from playing with matches. The less effective designs would be those aimed at preventing an accidental ignition caused by a shower of sparks.

DESIGN CONCEPT #1

Enclosed or sleeved striker surface--a basic concept upon which several allied but different designs can be based. See Figure 1. This concept is designed to discourage children from playing with matches by requiring the coordinated use of both hands. Further, it prevents adults from striking a match toward themselves with excessive force.

DESIGN FEATURES

1. The match to be struck is shielded by an enclosed channel and any sparks generated are aimed away from the virgin matches in the book.

2. Requires the use of both hands, hence, reasonable strength and dexterity are required.

   After the match to be struck is removed from the book the channel must be squeezed open slightly in order to effect the next step required: inserting the match head into the striking area. Finally, the channel must be pressed upon the match head and the match pulled from the channel across the striker plate to produce an ignition.

3. If the match ignites and remains in the channel, it speedily quenches itself. The striker strip, although damaged, still functions to ignite other matches.

4. The enclosed channel is open on both ends allowing both right and left handed persons to strike the match with equal ease.

5. A one-line, simple, instruction can describe the ignition procedure to new users.

6. Normal packing of matchbook is accommodated for only one additional thickness of paper--cover stock is added.

7. The striker area can be reduced making the operation still more difficult for children with only a correspondingly moderate increase in difficulty for adults.

8. The striker strip may be placed on the surface it is shown facing in the figure. In this case, if the sleeve is torn off, so is the striker.

9. Additional advertising space is provided on the striker cover.

UNDESIRABLE FEATURES

1. A slight addition in cost due to the use of a little more paper.

2. The striker cover can be torn off. (Concept 1C is proposed as an addition to the sleeved design to offset this particular problem. Also note feature number 8 above; if the cover is torn the striker is removed.)

DESIGN CONCEPT # 1

MATCHES

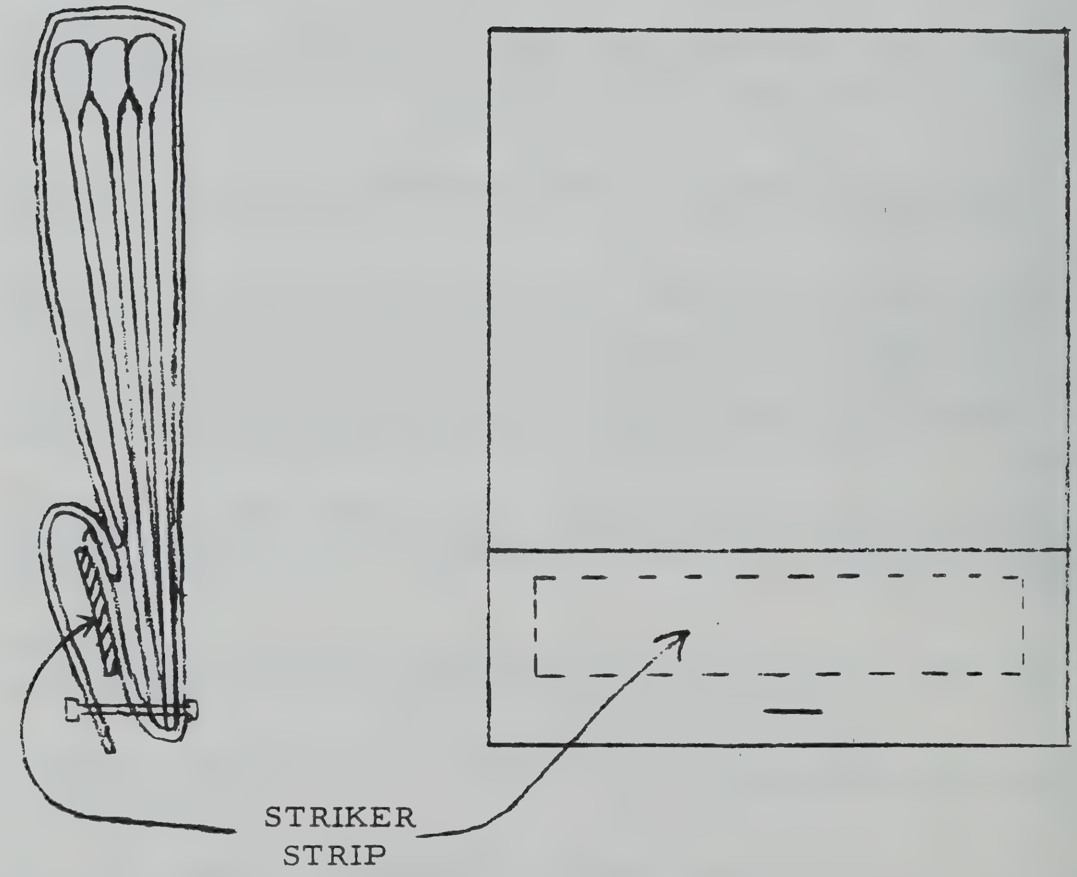


Figure # 1

DESIGN CONCEPT #1A

Enclosed Striker Surface Plus Dummy Striker

Add a dummy striking surface to the outside in normal position. See Figure 1A.

DESIGN FEATURES

1. Same as Basic Design Concept #1.

2. Very young children, up to 5 or 6 years of age, may be inclined to attempt to use the readily visible dummy striker strip with negative ignition results. Interest in achieving a flame could be dampened by this experience.

UNDESIRABLE FEATURES

1. An incremental addition in manufacturing costs.

2. May become an ineffective ruse after a period of time.

DESIGN CONCEPT #1A

MATCHES

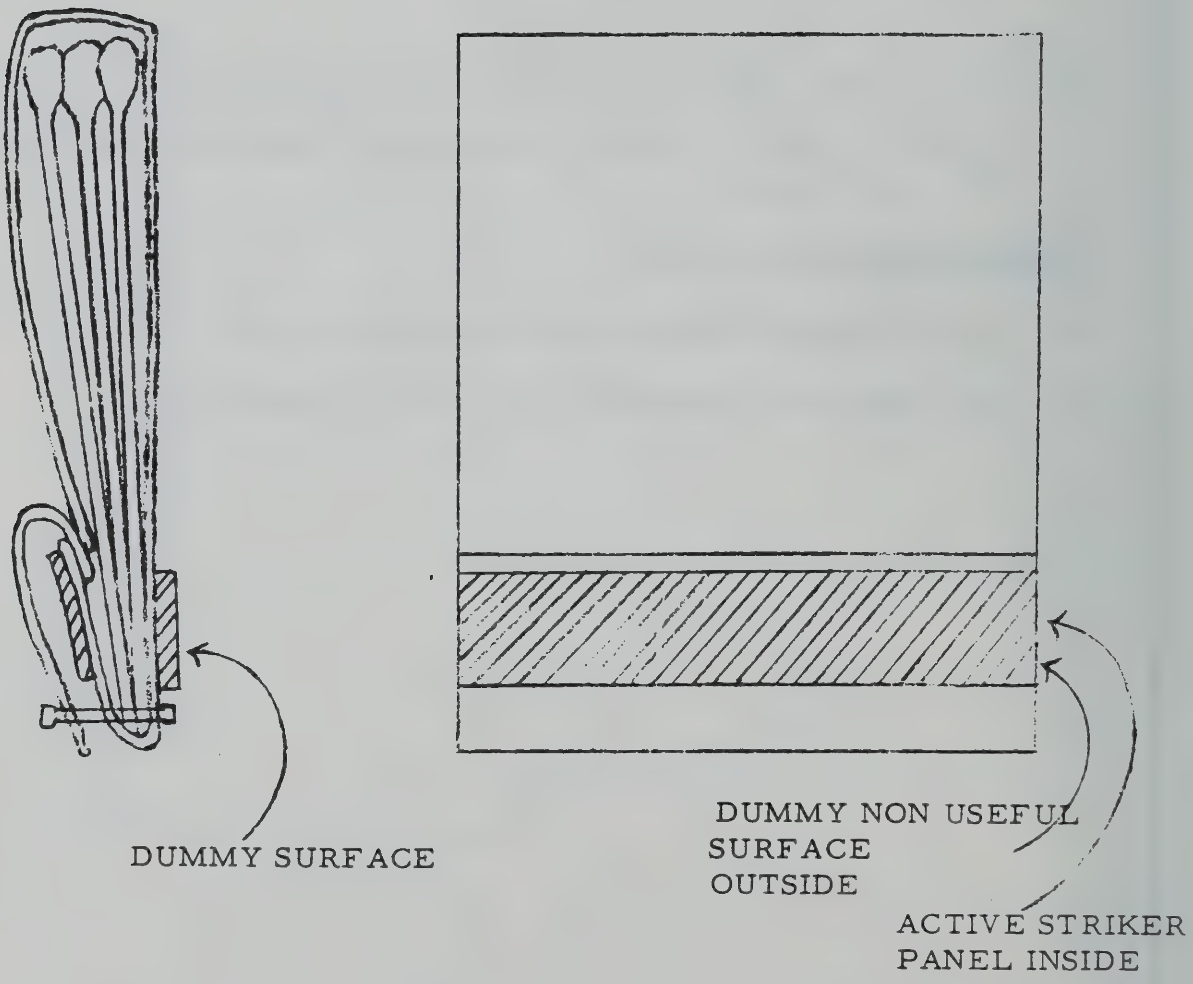


Figure # 2

DESIGN CONCEPT #1B

Enclosed striker surface, enclosed abrasive surface and an inert coating on match heads. See Figure 3.

DESIGN FEATURES

1. Same as Basic Design Concept #1.

2. Match heads are coated with a membrane material such as gum Arabic, silicone cement, water glass. Ignition is prevented until the membrane coating is abraded partially away. Then the match may be ignited in the striker channel. The additional channel is provided with an abrasive strip similar to sandpaper.

3. Children would be required to learn additional steps over the Basic Design Concept #1 requirements as well as the correct sequence of events.

4. The membrane coating damp-proofs the remaining virgin matches and additionally protects them from ignition sparks.

UNDESIRABLE FEATURES

This design prevents the present "Give Me a Quick Light", which most users expect. Deliberate actions in sequences are required and approximately five times present ignition time is possible (inconvenience to the user). Also there exists the ever present necessity of considering additions to the manufacturing costs.

DESIGN CONCEPT #1B

MATCHES

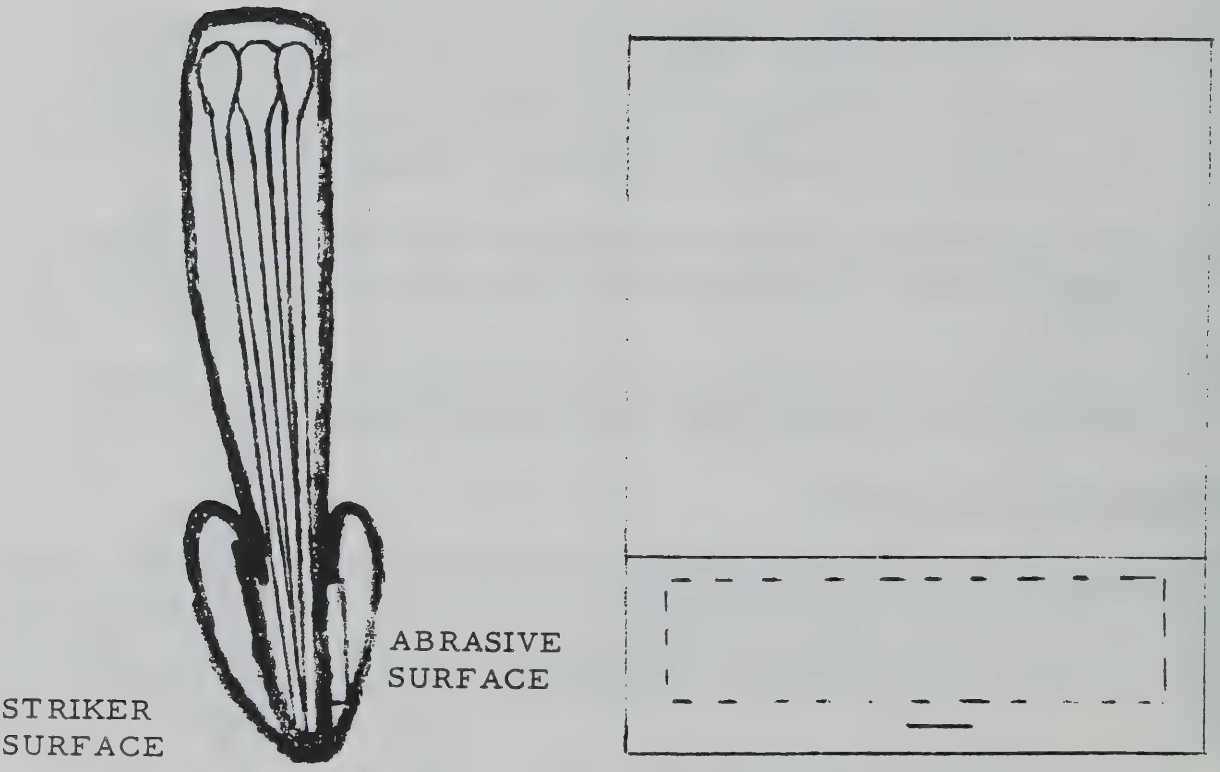


Figure #3

DESIGN CONCEPT #1C

Enclosed striker surface plus a thinner match. See Figure 4.

DESIGN FEATURES

1. **Same as Basic Design Concept #1.**

2. Since a pull motion is required to strike the match, stiffness of the stem is no longer a requirement. Therefore, a smaller or weakened stem is satisfactory.

3. Twenty of the thinned matches can be accommodated in each match sheet within the book. One entire sheet can be eliminated. Less head material, less paper per book, may result in a cost advantage.

4. It is nearly impossible to strike one of these tensile matches by striking down on the present open-striker surface. It can be done by holding the head against the surface with the finger. However, this technique is used by relatively few adults and most children would not be expected to light a match in this manner.

UNDESIRABLE FEATURES

1. The dipping techniques now used in manufacturing matches may not be usable with a weaker match stem. Some modification may be necessary, such as:

   - holding the stem closer to the head during any dipping process;

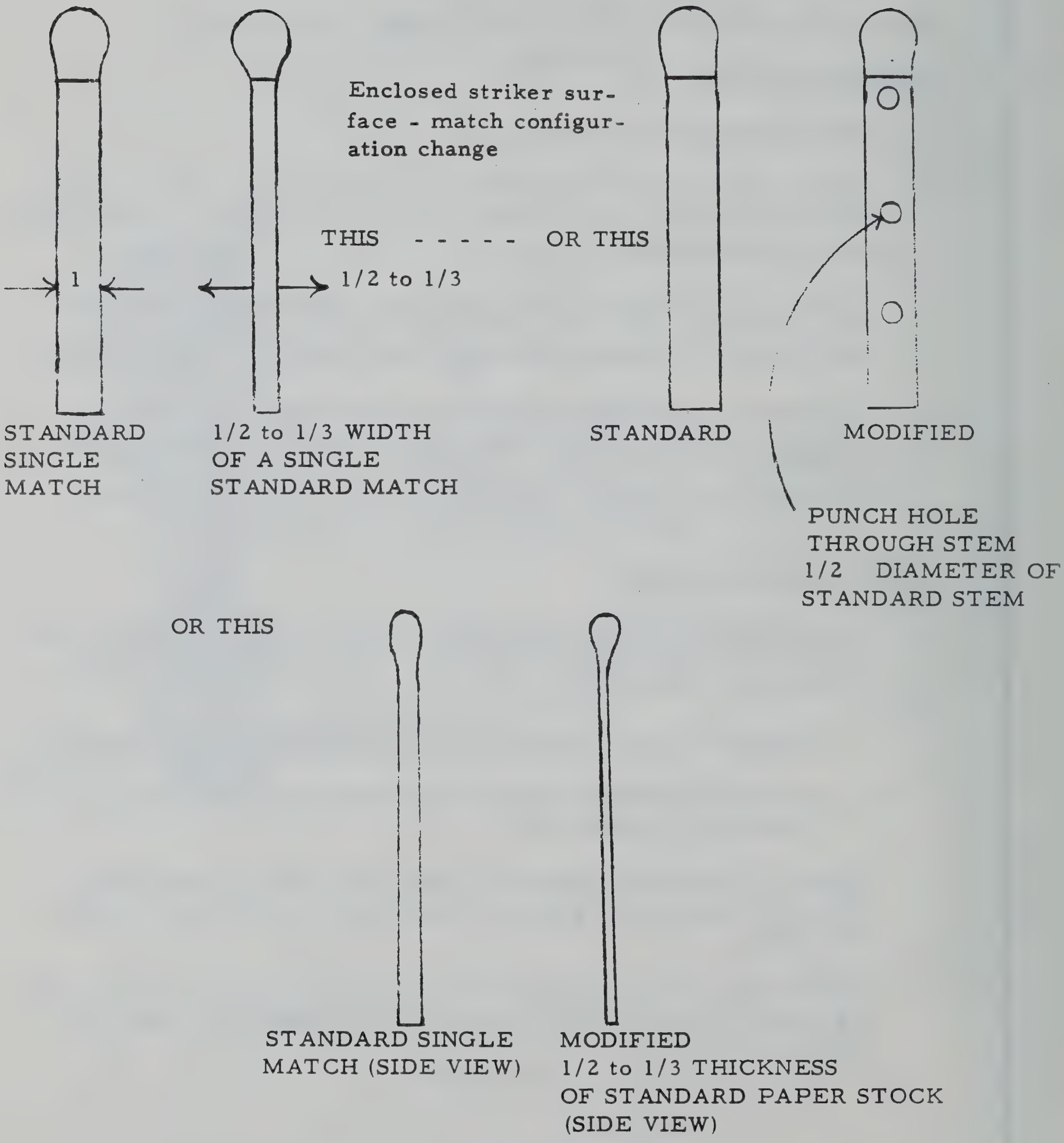
   - moving the matches through the paraffin and head coating mixture at a slower rate.

   These requirements, should they exist, may add an incremental amount to manufacturing costs, offsetting any gains made by using less paper.

2. If the striker cover is torn off, this design may cause a user to hold the match closer to its head, increasing any tendency to drop the match as it flares.

DESIGN CONCEPT #1C

MATCHES


Enclosed striker surface - match configuration change

THIS ----- OR THIS
1
1/2 to 1/3
STANDARD SINGLE MATCH
1/2 to 1/3 WIDTH OF A SINGLE STANDARD MATCH
STANDARD
MODIFIED
PUNCH HOLE THROUGH STEM 1/2 DIAMETER OF STANDARD STEM
OR THIS
STANDARD SINGLE MATCH (SIDE VIEW)
MODIFIED 1/2 to 1/3 THICKNESS OF STANDARD PAPER STOCK (SIDE VIEW)

Figure #4

DESIGN CONCEPT #2

Separate catalyst or component required prior to ignition. A two-step ignition sequence. See Figure 5.

Trace amounts of catalyst must be abraded or rubbed onto the match head from the catalyst strip (Step 1 of the sequence). The match is then struck, Step 2, on the striker strip either in conventional manner or as in Basic Design Concept #1. The objective of this design is to discourage children from playing with matches by imposing a sequence operation.

DESIGN FEATURES

1. The match is inert until trace amounts of "catalyst" are made to adhere to the head surface by pulling across the "catalyst" strip. Unless this step is accomplished first, the match will not ignite.

2. If the procedure is accomplished in reverse; that is, the match is pulled over the striker and then on the catalyst, no ignition is possible. However, if then struck on the striker, ignition will be accomplished.

3. The catalyst may be of such a nature as to require a rapid response time, say, 5 seconds between catalyst contact and striker usage. Children especially would find this operation very difficult.

UNDESIRABLE FEATURES

1. A catalyst would first have to be found.

2. A suitable strip would have to lose part of its contents for each match that is ignited. Consequently, determining the correct size and content of the catalyst strip would be a necessary research step.

3. The catalyst material would have to be both soft enough and sufficiently adhesive in character to be effective.

4. It must be assumed for the present that some increase in manufacturing costs will be necessary.

DESIGN CONCEPT #2

MATCHES

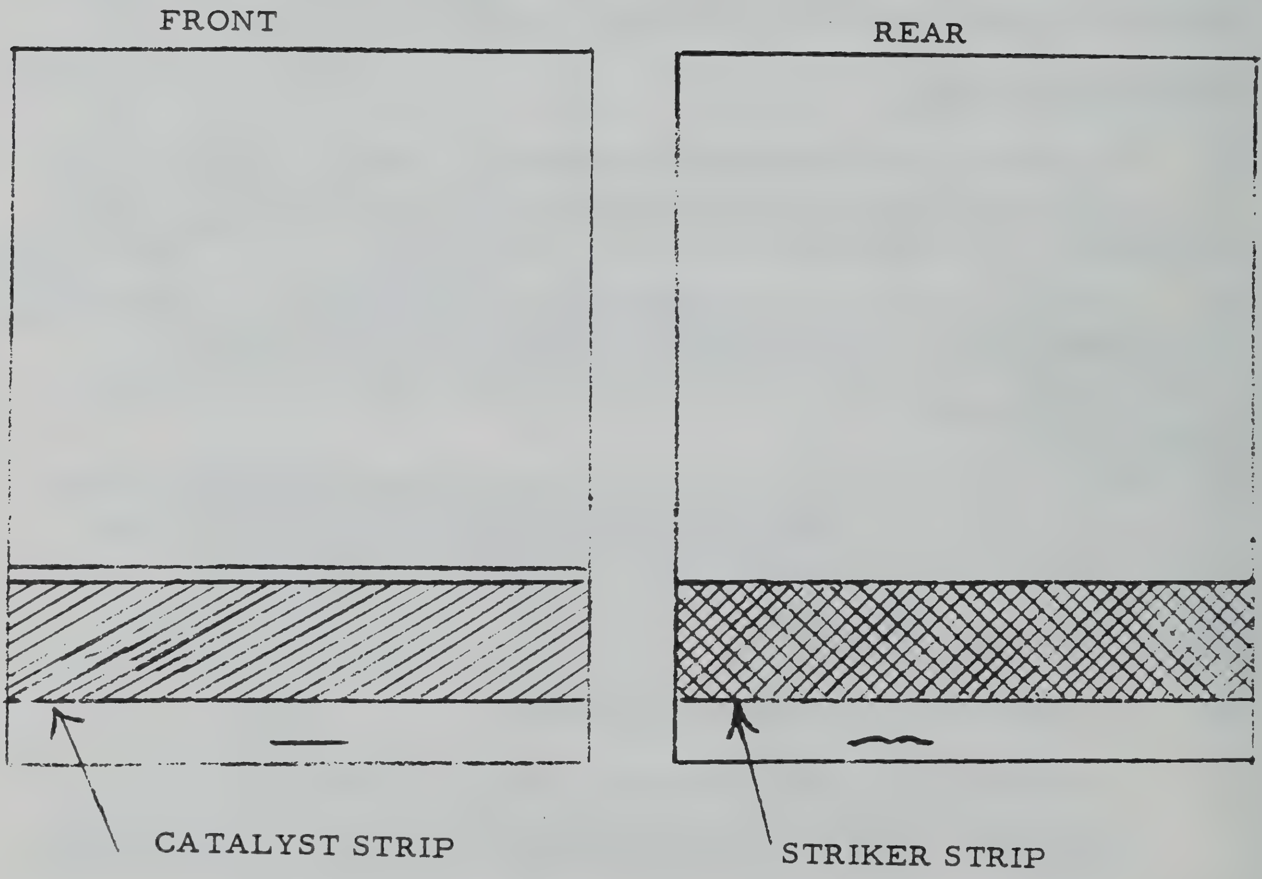


Figure #5

DESIGN CONCEPT #3

Limit the burning time of the match to about four to five seconds total duration. See Figure 6.

A normal match burns approximately 25 seconds down to the end. If a fire quench or retardant material is impregnated into the match stick, then the match can be made to burn for a prescribed length of time.

DESIGN FEATURES

1. Trial tests show that cigarettes (the primary use of matches) require only about three to five seconds of flame duration for lighting. Fireplace fires can also be initiated in this length of time. Gas burners are ignited in even less time. Since the three to five seconds is only a crude approximation of the desired burning time, more detailed determinations can be made to establish the desired time interval.
2. The fire hazard associated with an ignition sequence where the match is dropped would be considerably reduced.
3. The shorter flame duration may provide some reduction of interest by children who delight in watching the flame. Since the match will not burn past the flame-retardant area, children would be less likely to burn their fingers, which, in many cases, causes them to drop the burning match.

UNDESIRABLE FEATURES

1. Pipes and cigars would be more difficult to light with the short flame duration match.
2. Camp fires, etc., in damp or wet weather would be difficult or impossible to light since a considerable heat pulse can be required.
3. Special matches may be required for these and other specific lighting tasks.

COMMENT

Inhibition of the flame can be effected by using a higher concentration of treating solution at the paper mill. Alternately, it can be accomplished by dipping the bottom portion of the match in a retardant chemical. See "Approved List of Flame Retardant Application Concerns, Fabrics, Materials and Chemicals" published by the State Fire Marshal, Sacramento, California.

DESIGN CONCEPT #3

MATCHES

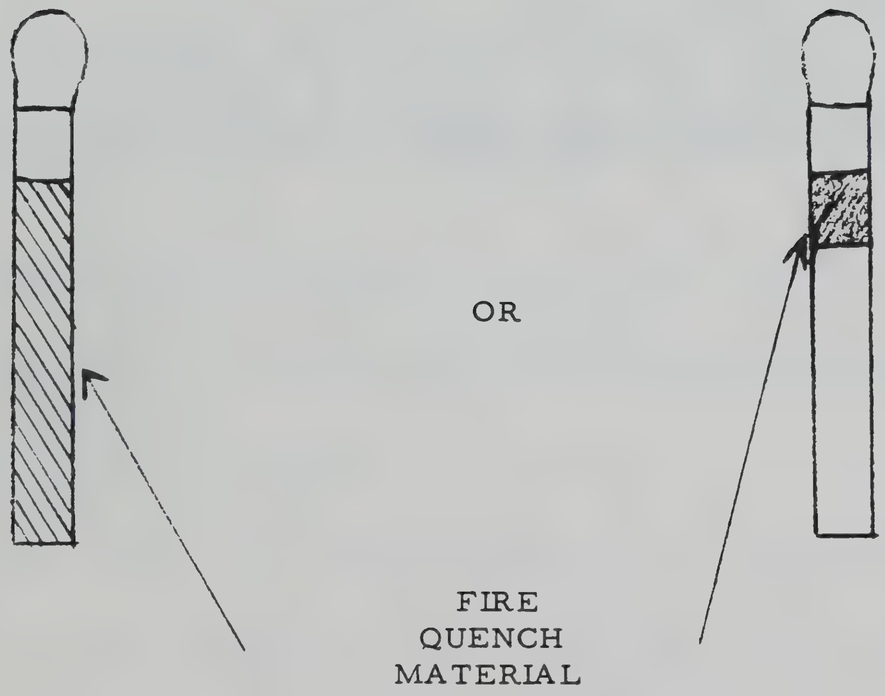


Figure #6

DESIGN CONCEPT #4

Colite "Fire Pruf" Match

This match has been recently designed by the Cahn Brothers of The Colonial Alloys Company, Philadelphia, Pennsylvania. It is designed to reduce the hazards associated with a dropped match and to discourage children who enjoy watching a flame. Its major safety features are:

1. A feeble flame

2. Match must be held inverted to prolong the life of the flame. Holding the match any other way or dropping it causes it to extinguish. Therefore, the match remains lit only so long as it is consciously used.

DESIGN CONCEPT #5

Provide a separate striker strip to be attached to the matchbook by the user. A contact adhesive-backed striker strip with a peel-off protective covering would be included with the matchbook. See Figure 7. This concept has the purpose of discouraging children from igniting matches.

DESIGN FEATURES

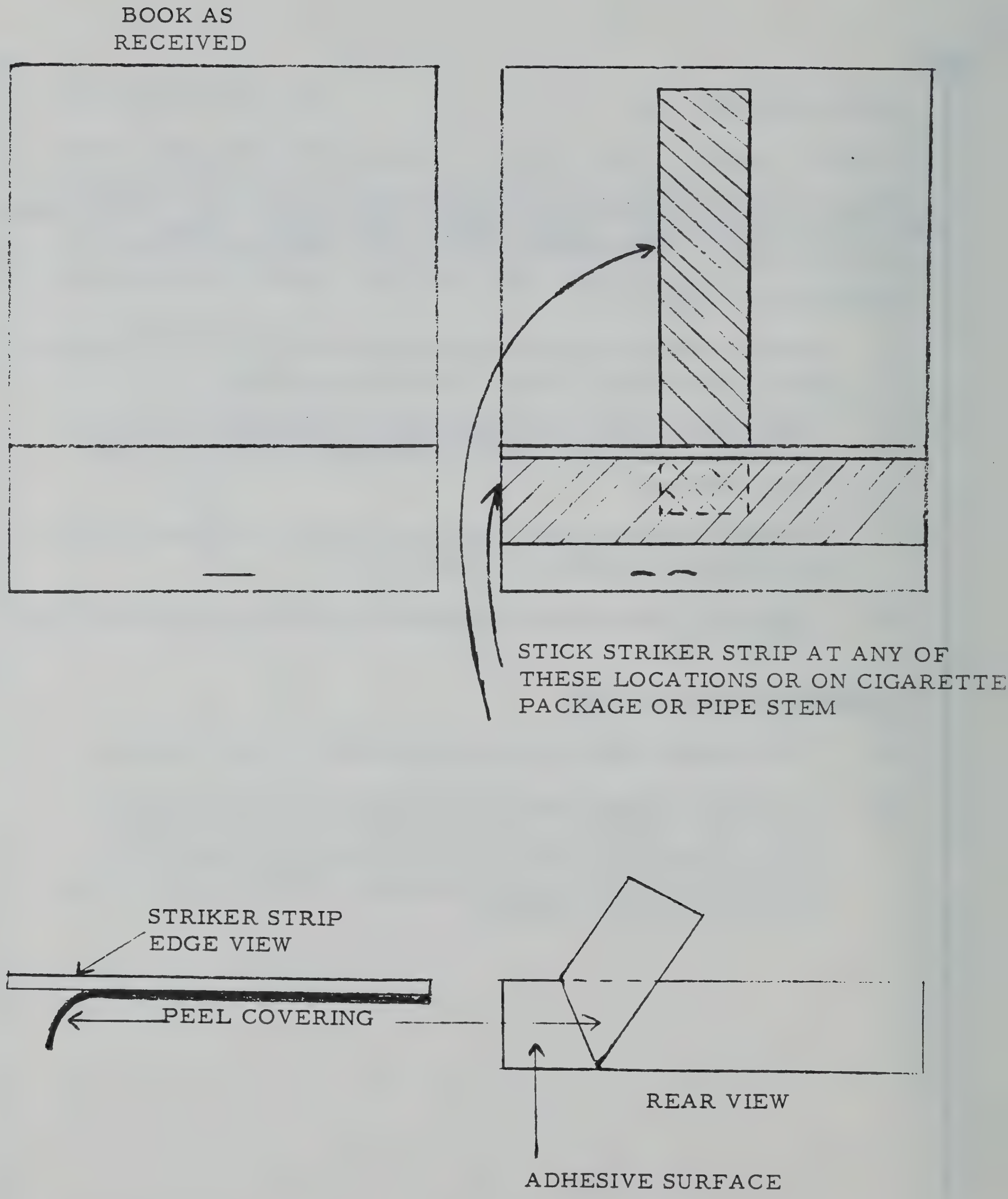
1. Books or boxes of matches as received would be, for all practical purposes, inert until the striker strip is installed.
2. Tests indicate that three or four books of matches can be ignited from one striker strip. This could allow re-use of the striker strip if desired.
3. Matches around the house can be made inert if the striker strip is not attached or is stored in a safe place.
4. Additional advertising can be obtained by printing on the back of the striker strip.

UNDESIRABLE FEATURES

1. This concept requires some inconvenience to bona fide users.
2. A warning message would have to be printed on the striker or match cover advising users to keep the striker in a separate location from the matchbook or, to locate the striker on the matchbook in a non-hazardous position, should he desire to keep matches and striker together.

DESIGN CONCEPT #5

MATCHES



STICK STRIKER STRIP AT ANY OF THESE LOCATIONS OR ON CIGARETTE PACKAGE OR PIPE STEM

Figure #7

DESIGN CONCEPT #6

Move striker plate from present position to a vertical position at the rear of the book.

DESIGN FEATURE

The striking direction, either up or down, is always away from the unstruck matches in the book. This design is intended to prevent the spark ignition of the remainder of the book, even if the front flap is open. A striker placed in a horizontal location on the rear is less desirable for the striking motion allows sparks to ignite the exposed sides of matches, even within an enclosed book. This is not an uncommon occurrence. People in the match industry go so far as to recommend holding the thumb over the unused match heads just to avoid this event.

UNDESIRABLE FEATURES

Printing the striker strip vertically would require a change from present continuous printing systems. Further it would require a re-orientation of advertising space.

DESIGN CONCEPT # 6

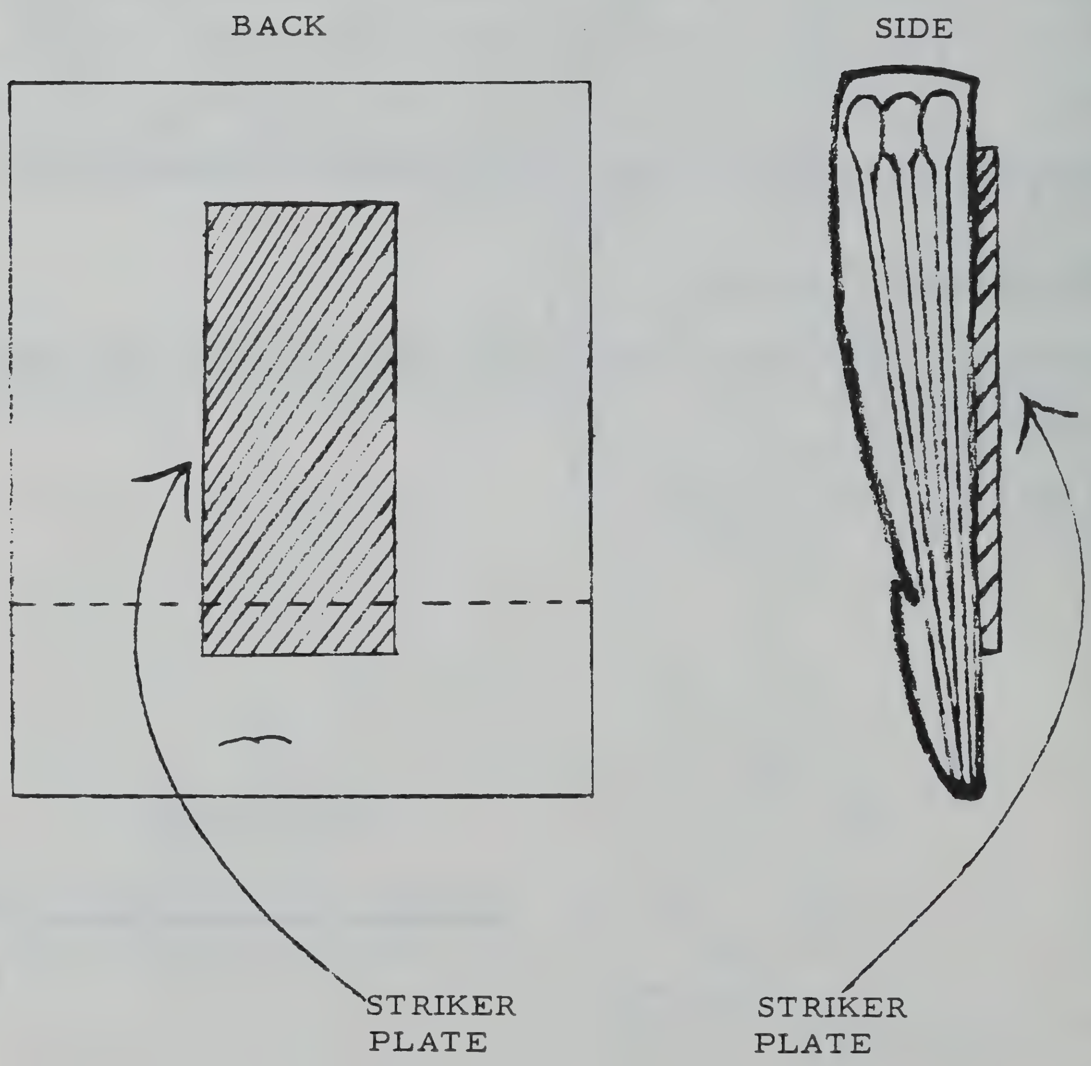


Figure # 8

DESIGN CONCEPT #7

Enviro-Degradable Matches--a passive protective scheme

Match heads are not dipped in a sealer but have a small amount of hydroscopic material such as $CaCl_2$ added or dusted on the heads, or have an increased percentage of glue. Upon exposure to normal air and humidity the heads become soft and not usable within a few days or weeks.

DESIGN FEATURES

1. Full or partial books of matches accumulated around a home become non-usable in a short length of time. If found by a child after this time period, the matches will be inert and cannot be ignited.
2. Matchbooks would be packaged in, say, groups of 6 to 10 in sealed pouches prior to packing in standard boxes. At distribution points, pouches would be broken to provide single books at the time of need. Normal use would require only about two days of use life.

UNDESIRABLE FEATURES

Shelf life would be highly dependent on relative humidity levels of the air. Cost of manufacture would rise and current distribution practices would have to be drastically modified. Further, the hydroscopic material would have to be found to provide water accumulation at an acceptable rate over a wide humidity range.

DESIGN CONCEPT #8

Thread or weave aluminum foil channel over the four individual rows of matches in the folder. Only one of the remaining match heads would be exposed at any time. See Figure 2. This design is aimed at preventing the book-ignition type of sequence. Further, it is intended that the foil provide a visible reminder that safer handling of matches is an objective of daily concern.

DESIGN FEATURES

1. Each individual match but one is shielded from sparks of any match being struck.

2. The heat dissipation capacity of the aluminum prevents all virgin match ignitions even if a burning match is placed on the aluminum covering heads. A burning cigarette can be placed on the foil and no ignition of remaining matches results.

3. Even with the cover open, no ignition of the virgin matches can be effected (checked by testing).

UNDESIRABLE FEATURES

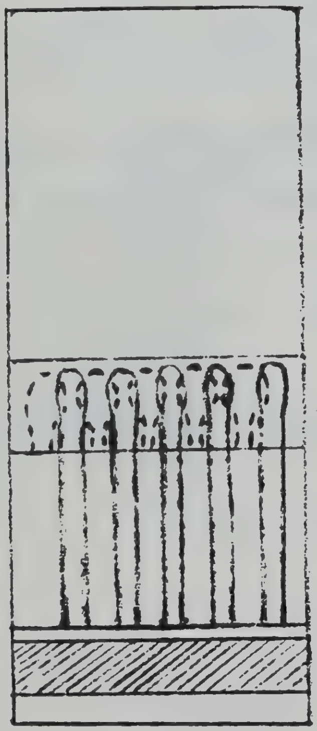
1. Matches to be struck are a little more difficult to remove from the book.

2. A new assembly step during manufacture is required. This plus the addition of aluminum foil would increase manufacturing costs, now estimated to be 1/4¢ per book.

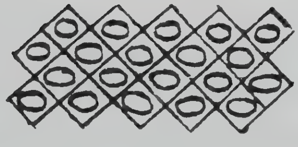
DESIGN CONCEPT # 8

MATCHES

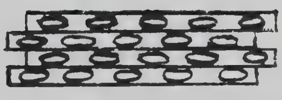
FRONT

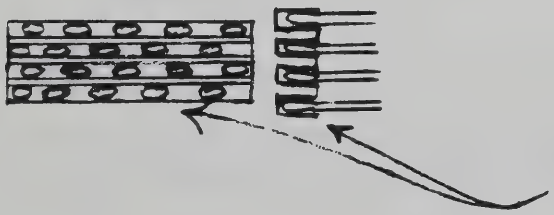


TOP



LATTICE ASSEMBLY
ALTERNATE





Crimped aluminum foil 4 channels wide approximately 1-1/4" long. Each row of matches covered by a channel. Channel automatically crimped in place when cover is folded during manufacture.

Figure #9

DESIGN CONCEPTS

LIGHTERS

Only Design Concepts 1, 2, and 3 are demonstrated by sketches in this study. Several other concepts are simply listed. These are considered viable possibilities but require further effort to finalize. Consequently, the details of their operation are considered to be beyond the scope of this study.

The first three concepts have been placed in a sequence to reflect a trend of decreasing order of effectiveness in reducing accidental ignitions. Thereafter, each of those concepts which were simply listed were placed in a decreasing order of effectiveness. Finally, a butane lighter was inserted into the rating chart for comparison with liquid fuel lighters. The more effective designs would be those aimed at preventing or discouraging children from playing with a lighter.

DESIGN CONCEPT #1

Limit the flame duration of a lighter by metering the amount of fuel available for each ignition operation. See Figure 10. This concept is one of several directed at reducing the hazard of a dropped lighter. It is also directed at creating a difficult set of operations for children.

OPERATING SEQUENCE

1. Open top of lighter
2. Charging button release actuated
3. Charging button is pushed in pumping a predetermined amount of fuel into the wick chamber. The wick absorbs the fuel.
4. The flint is struck in the conventional manner.
5. The top is closed releasing the pump lock and extinguishing the flame.

DESIGN FEATURES

1. Only the desired metered fuel supply for a predetermined burning time is made available to the wick.
2. Once the charging button is depressed and injects the metered fuel it is locked "in" by the pump lock and cannot be actuated again until the top is closed. Only one metered fuel charge can be made for each lighting cycle.
3. The top, being spring loaded, must be held open by gripping the lighter body.

COMMENT:

A spring loaded top is a feature now in use on some commercial lighters. It is a simple and effective means of reducing the hazard of a dropped lighter.

DESIGN CONCEPT #1

LIGHTERS

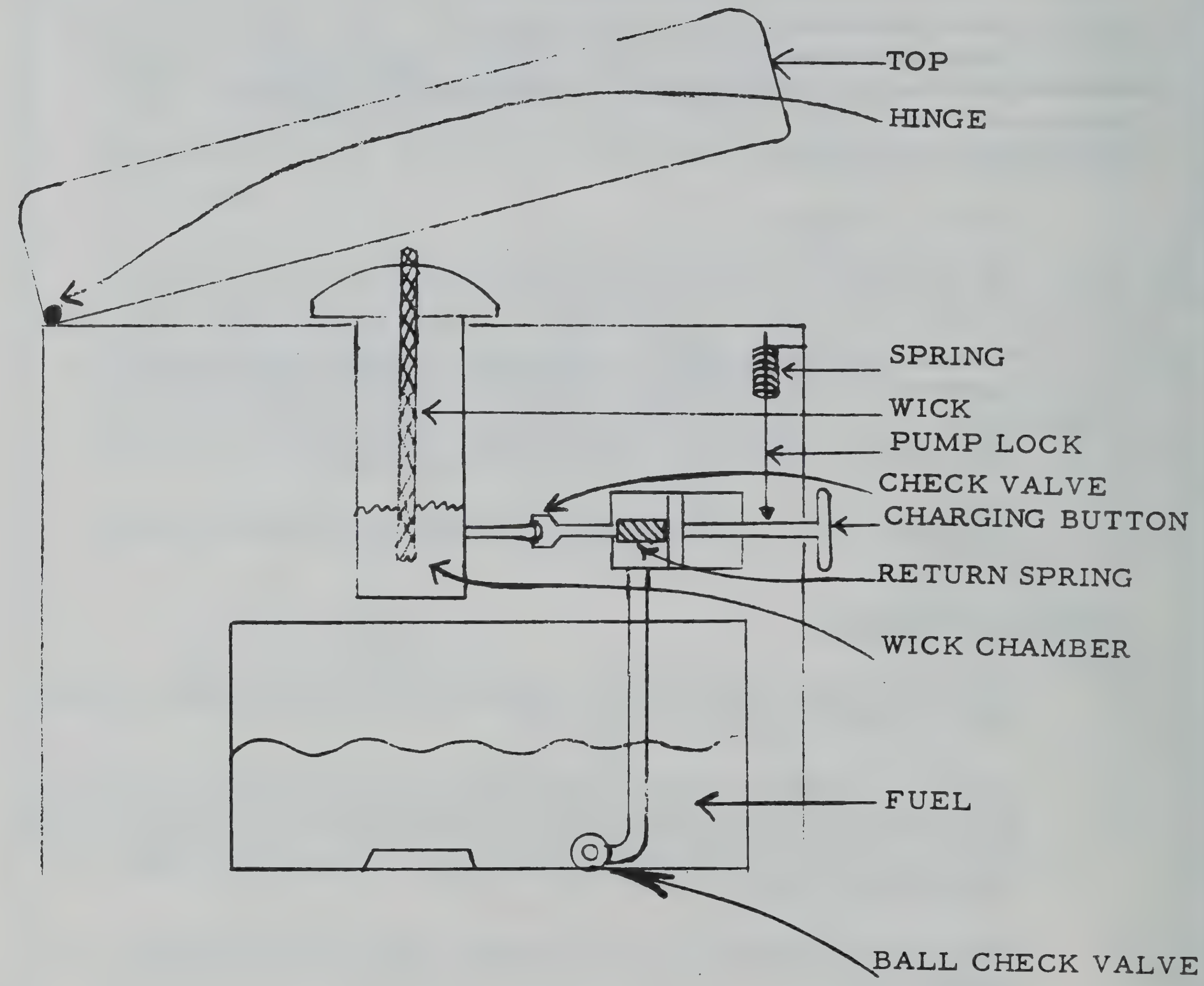


Figure # 10

DESIGN CONCEPT #2

Flame enclosed within a screen mesh (Davy Cage). See Figure 11. The objective of this design is to prevent unintended ignitions resulting from a short contact time with the flame.

DESIGN FEATURES

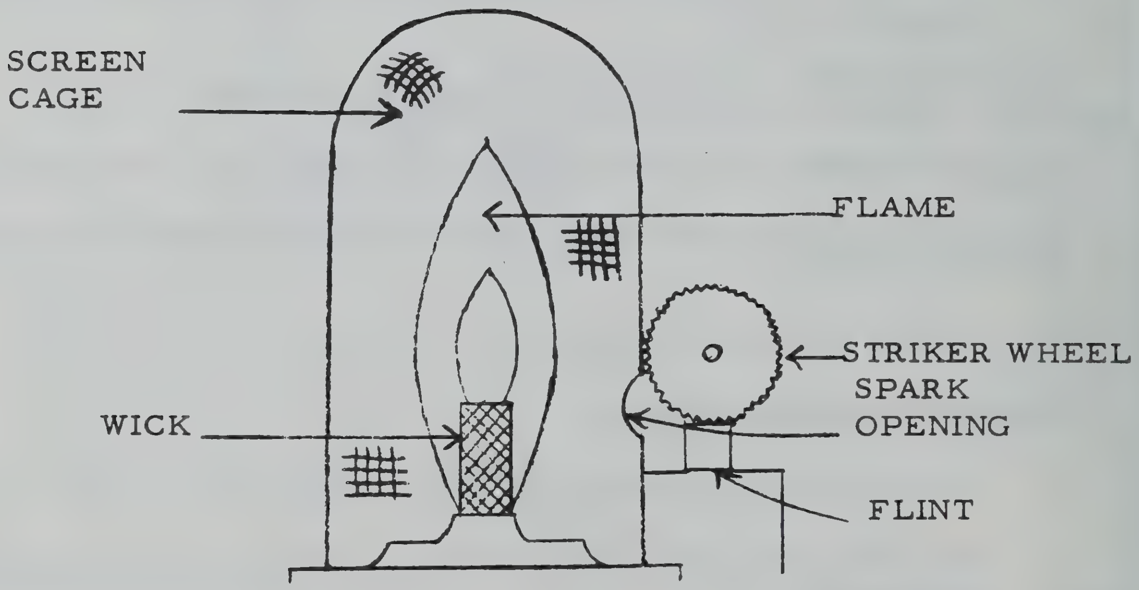
1. Direct contact between the high temperature flame and any fabric is prevented.
2. The screen surface is generally at a much lower temperature than the naked flame.
3. Explosive hazard to combustible gaseous atmospheres is decreased (miner's lamp).
4. Flame is provided with an excellent wind screen.
5. A cigarette or cigar tip is placed directly on the screen for ignition.
6. Flame flicker minimized. May not be as appealing to children as an open flame.
7. Flame size can be reduced.

UNDESIRABLE FEATURES

1. Not suitable for lighting pipes.
2. Screen may become clogged with use and have to be replaced or cleaned.
3. Only corrosion-resistant materials can be used for the screen.
4. A lock-in-place system for the screen must be child-proof.
5. Other materials such as paper or clothing can still be ignited by direct and prolonged contact with the screen.

DESIGN CONCEPT # 2

LIGHTERS



A screen Davy Cage surrounds the flame

Figure # 11

DESIGN CONCEPT #3

Dual sequence ignition system, hidden flame. In this design, the flint and wick region of the lighter remain hidden until the top portion of the lighter is twisted approximately 15 degrees. When the twisting is accomplished, this region becomes exposed by virtue of its being aligned with a lighting port. Return of the lighter top to its closed position is effected by a spring mechanism which acts when the grip on the top portion is released. The objective here is to make lighters sufficiently difficult to operate so that children will be discouraged from playing with them. See Figure 12.

DESIGN FEATURES

1. Flame is contained in the center of the body cylinder.
2. Cigarettes or cigars must be guided and placed into the lighting part while manually holding the top in lighting position against the return spring tongue.
3. The small flame, being in the center, cannot be made to issue outside the lighter body. Ignition of materials other than cigarettes or other cylindrical items of that size is minimized.

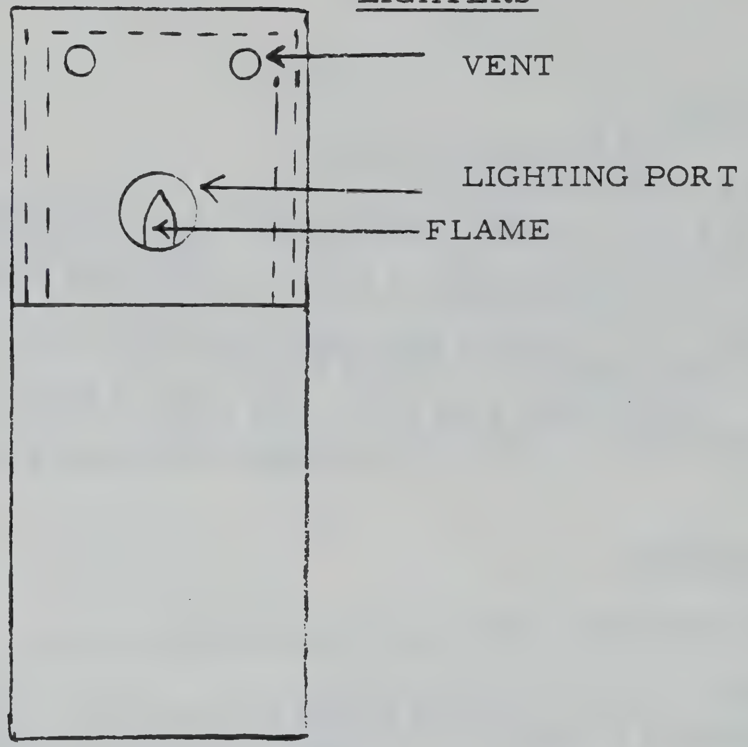
UNDESIRABLE FEATURES

1. Not suitable for pipes.
2. If dropped or struck, the rotating mating surfaces may be dented and operation prevented or made difficult.
3. Papers and other fabrics may still be ignited if deliberately thrust into the opening.

DESIGN CONCEPT #3

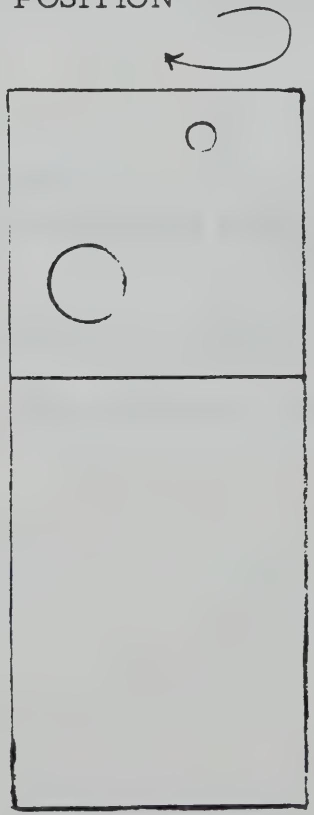
LIGHTERS

LIGHTING POSITION



SIDE VIEWS

STOWED POSITION



Top has moved approximately 15 °
closing lighting port and vent ports.

Figure #12

DESIGN CONCEPT #4

Design an interlock ignition sequence that requires 2 discrete steps or manual operations to ignite. The objective is to discourage the use of the lighter by children. Some commercial lighters now include this feature.

DESIGN CONCEPT #5

Prepackaged fuel refill cartridges. The cartridges are inserted directly into the lighter body and discarded when empty. This will reduce the hazard that accompanies spillage of lighter fluid. This feature is already available in butane lighters.

DESIGN CONCEPT #6

Design the lighter body so that a flame is maintained only by retaining a grip on the lighter. If the grip is relaxed, the flame is extinguished. This design is available on some lighters now on the market. Its value is that it reduces the hazard of the ignition sequence associated with dropping the lighter.

DESIGN CONCEPT #7

Make the surface of the lighter sufficiently rough so as not to be slippery even if coated with lighter fuel. The purpose here is to reduce the probability of dropping a lighter.

A COMPARATIVE RATING SYSTEM FOR NEW DESIGN CONCEPTS

Three rating factors were used in comparing the effectiveness of various conceptual designs. These factors were:

1. SAFETY FACTOR--This is a measure of the safety qualities of any design when compared to a standard. The standards chosen were the book match and a commercial liquid fuel lighter which continues to provide a flame even when dropped. The standards were assigned a value of 1. Any design assigned a value greater than 1 is considered to be safer than the standard and vice-versa.

2. ACCEPTANCE FACTOR--This is a measure of the anticipated degree of acceptance or rejection by the public. A value of 1 is assigned to the standards. A concept assigned a value greater than 1 would be judged as being more desirable by the public and vice-versa.

3. ECONOMIC IMPACT--This factor provides an index of the relative cost of a new design when compared to the standard. A value greater than 1 indicates that the new design would be less costly than the standard, which has a value of 1. The converse would be true for any assignment of a number smaller than 1. This factor may be further visualized as being equal to (1-cost % change), where cost % change is positive if the new article is more expensive than the standard and negative if it is less expensive.

An "Overall Degree of Desirability" is arrived at by multiplying the three factors and comparing the results against the standard and against one another. Note that the standard has an overall index of 1. Tables I and II on the following pages show the results of application of the rating system to each new concept. It must again be emphasized that the numbers shown therein reflect only the judgments of the investigators.

In assigning the safety index, the investigators chose a number between 0 and 2. Two would represent the highest advancement in safety possible. The concepts judged safer were selected first and assigned an estimated safety index. Thereafter, all concepts were placed in a decreasing order of safety value. Following this, the acceptance and economic factors were estimated for each concept. With all three numbers assigned, the overall index could easily be calculated.

COMPARATIVE EFFECTIVENESS RATINGS

MATCHES

DESIGN	SAFETY FACTOR	ACCEPTANCE FACTOR	ECONOMIC FACTOR 1 - COST % CHANGE	OVERALL INDEX OF DESIRABILITY SAFETY FACTOR X ACCEPTANCE FACTOR X ECONOMIC FACTOR = SCORE
Standard Safety Match (Reference)	1	1	1	1
#1 Enclosed Striker Surface	1.5	0.85	0.95	1.21
#1A Add Dummy Striker	1.6	0.83	0.92	1.22
#1B Add Abrasive Surface Coat Heads	1.8	0.8	0.83	1.19
#1C Thin Match	1.7	0.84	1.2	1.71
#1 +A +B +C	1.8	0.85	1.2	1.84
#2 Separate Catalyst	2.0	0.8	0.7	1.12

COMPARATIVE EFFECTIVENESS RATINGS

MATCHES (continued)

2 A +B +C #6	2.0	0.83	1.1	1.83
3 Limit Burning imes	1.6	0.83	1.1	1.83
4 Cahn Match Patent Pending)	1.6	0.8	0.7	0.90
5 eparate Striker	1.2	0.9	0.95	1.03
6 triker Vertical n Back of Book	1.2	1	0.9	1.08
7 nvirodegradable	1.1	0.8	1	0.88
8 irgin Match Heads Protected by Foil	1.1	0.9	0.8	0.79

COMPARATIVE EFFECTIVENESS RATINGS

LIGHTERS

DESIGN	SAFETY FACTOR	ACCEPTANCE	ECONOMIC FACTOR (1 - COST % CHANGE)	OVERALL INDEX OF DESIRABILITY SCORE (S. F. x A. F. x E. F.)
Inexpensive, liquid fuel Lighters	1	1	1	1
#1 Limit Fuel Duration	1.8	0.92	0.9	1.49
#2 Davy Cage Screen	1.8	0.95	0.97	1.65
#3 Hidden Flame	1.5	0.95	0.9	1.28
#4 2-Step Interlock	1.8	0.95	0.95	1.62
#5 Prepackaged Fuel	1.6	0.95	0.95	1.44
#6 Grip Required	1.4	0.95	0.95	1.26
#7 Rough Surface	1.2	0.95	0.15	1.14
#8 French Rabbit Butane-Lighters	1.4	1	1	1.4

REFERENCES

(1) National Bureau of Standards Report 10,629 - "Ignition Sources in Accident Cases Involving Flammable Fabrics" by Henry Tovey and Richard Giroux.

(2) "Matches and Lighters, Observations" FFACTS, November 23, 1971.

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National Bureau of Standards.

APPENDIX I

SYNOPSIS OF INVESTIGATOR'S PHILOSOPHY

1. Any design change considered must still allow the match or lighter to function usefully as an ignition source for normal usage.

2. The youngest age segments of the population will be protected where possible, by design changes that capitalize on normal child behavior.

3. The sequence of events extracted from the accident report files will be used to steer the design changes towards circumvention of common reported causes and eliminating hazardous sequence steps where possible.

4. Redesign avenues are to be considered with only a general and preliminary regard for economic penalties.

5. Some inconvenience to the middle age population groups will be tolerated if the remaining segments of the population are protected by the redesign features.

6. Since playing with matches by children is the most frequent activity in the reported accidents, child-proofing is to be a major objective. Dexterity, strength, and coordination of normal children and the 60+, elderly and/or handicapped age groups will be a consideration.

7. Abnormal usage of matches and lighters will receive only minor consideration and not as prime; i.e., shaving match heads and assembling a match rocket, firing matches as projectiles from an air rifle, using a lighter for a candle.

8. Even though a minor portion of reported accidents involve flaring of an entire book of matches, possible reduction of this hazard is to be considered.

9. Accidents involving gasoline or other flammable liquids or gases can only be considered as secondary with the exception of lighter fuels. Prevention of undesired or unauthorized match ignition in these cases appears to be the only alternative.

APPENDIX II

TRIDENT ENGINEERING ASSOCIATES, INC

PROPOSED STATEMENT OF WORK

MATCHES AND LIGHTERS ANALYSIS

PHASE I

PURPOSE

To define the hazardous problems of matches and lighters in terms of documented sources of ignition in fire accidents involving fabrics.

To determine within contract funding limits as many technical approaches or solutions as possible to the problem that could alleviate the majority of the use/incident cases presented in the FFACTS data.

Review the narrations of the filed accident cases and the FFACTS data base. Analyze in detail the chain of events that led to the injury in several cases. Determine common events in the analyses.

Based on the findings of the problem and in conjunction with the analysis, recommend how matches and lighters could be redesigned economically to effect varying degrees of reduction in the hazard.

APPROACH

1. Problem definition--use National Bureau of Standards Report 10/629 and the document "Matches and Lighters (FFACTS November 23, 1971) Observations" to provide the statistical accident data baseline for conduct of the study.

   Examine the data as presented in Tables I, II, III, and IV and determine any other meaningful observations or relationships that could provide further insight into the problem.

   Concentrate problem definition efforts on those areas contributing to the greatest percentage of ignition incidents and document separately in a descending order of occurrence for both matches and lighters.

2. Outline ground rules for scoping the possible redesign of both lighters and matches. Determine and define those ground rules applicable to matches and lighters. Treat each separately.

Consider operating personnel characteristics such as age, dexterity, attention span, activity, etc. Also consider the ignition source characteristics such as complexity to ignite, mode of use, reliability of ignition flame duration, flame size, etc.

3. Generate and briefly describe possible design changes that can be accommodated within the ground rules.

4. Prepare conceptual design sketches of each credible design change as described in 3, above.

5. Where possible, especially on book matches, prepare a mock-up representing the concept and a sample batch for testing.

6. Apply economic judgment as to practicality of individual concepts and make an incremental cost comparison for the selected redesign features. Rate the proposed concepts for acceptability and prepare a final report for the most promising concepts which will include both matches and lighters.

PHASE II

PURPOSE

Refine the results of Phase I by considering new data made available and deemed pertinent by NBS during and since Phase I. Modify ground rules, where appropriate as dictated by the new data inputs.

Prepare conceptual design sketches of each credible design change suggested by the data refinement but in consonance with Phase I conceptuals.

Construct mechanical working mock-ups of lighters with derived design changes. Design change possibilities

Table lighters - new configuration
Pocket lighters - new configuration
Table lighters - modify existing configuration
Pocket lighters - modify existing configuration
Table or Pocket lighters - new concept

Prepare and deliver one or two of the above possibilities for demonstration.

PHASE III

PURPOSE

Include human factor analysis of Phase I findings and resulting considerations, merged into redesign parameters to evolve a further reduction in hazards for both matches and lighters.

APPROACH

Contingent upon results obtained in Phase I.

NOTE: The costs attached herewith for Phases II and III are preliminary estimates indicating the order of magnitude for these Phases. At the conclusion of Phase I, costs for Phases II and III will be re-estimated and confirmed or revised.

March 28, 1972

NBS-114A (REV. 2-80)

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Annapolis, Maryland

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Trident# 0197-461S

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National Bureau of Standards
U.S. Department of Commerce
Gaithersburg, MD 20899

10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

A match or cigarette ligher is frequently the source of ignition in fires involving the accidental burning of fabric items. Consequently, any design of book matches or lighters which would contribute to their utilization in a safer manner would be highly desirable. In this report, eight design modifications for book matches and seven modifications for cigarette lighters are described and discussed. The objective of the new designs is to prevent the accidental ignition of clothing or other fabric material when used by children in a play situation or when used for a bona fide application by the adult population. The designs proceeded from a study of ignition sequences gleaned from accident reports filed with the National Bureau of Standards. A review of the reports revealed that, of the accidents in which matches and lighters were a factor, the majority were match-related and occurred in the 0-10 age group. Based on these findings, emphasis was placed on developing a safer match design for the protection of the very young. In order to apply some quantitative index of value, a rating system was devised in which added safety, anticipated acceptance by the public and costs were considered to ascertain the net value of each concept.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

burns (injuries); fabrics; flammable fabrics; ignition hazards; ignition sources; injuries; lighters; matches.

13. AVAILABILITY

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